CHAPTER 4

FUNDAMENTALS OF FIRE FIGHTING

Fire is a constant potential hazard aboard ship. You must take all possible measures to prevent fires from starting. If a fire does start, you must immediately report the fire to the officer of the deck and then extinguish it rapidly. Often a fire will start in conjunction with other damage caused by enemy action, storms, or an accident, Some fires are caused by Hull Maintenance Technicians doing welding, brazing, or cutting. Fires must be extinguished rapidly. Otherwise, they could easily cause more damage than the initial casualty. In fact, a fire could cause the loss of a ship even after the original damage has been repaired or minimized.

As a Damage Controlman, you will need to know a great deal about fires, You need to know how to identify the different classes of fires, how to extinguish them, and how to use and maintain the fire fighting equipment systems and equipment. The more you learn, the more you will be able to contribute effectively to the safety of your ship.

In this chapter, we deal with the fundamentals of fire fighting. These include the nature of fire, the classification of fires, the fundamentals of extinguishment, and the extinguishing agents used.

FIRE COMPONENTS

Three components are required for a fire. These are a combustible material, a sufficiently high temperature, and a supply of oxygen. You will hear these components referred to as the *fire triangle* consisting of fuel, heat, and oxygen (fig. 4-l). Fires are generally controlled and extinguished by eliminating one side of the fire triangle. That is, if you remove either the fuel, heat, or oxygen, you can prevent or extinguish a fire. We will discuss the extinguishment of fires later in this chapter.

HEAT

Fire is also called burning or combustion. This is a rapid chemical reaction that releases energy in the form of light and noticeable heat. Most combustion involves rapid OXIDATION. Oxidation is the chemical reaction by which oxygen combines chemically with the elements of the burning substance.

Even when oxidation proceeds slowly, such as a piece of iron rusting, a small amount of heat is generated. However, this heat usually dissipates before there is any noticeable rise in the temperature of the material being oxidized. With certain types of materials, slow oxidation can turn into fast oxidation (fire) if the heat is not dissipated, These materials are normally stowed in a confined space where the heat of oxidation cannot be dissipated rapidly enough. This is known as *spontaneous combustion*. Materials such as rags or papers that are soaked with either animal fats, vegetable fats, paints, or solvents are particularly subject to spontaneous combustion.

For a combustible fuel or substance to catch on fire, it must have an ignition source and be hot enough to burn. The lowest temperature at

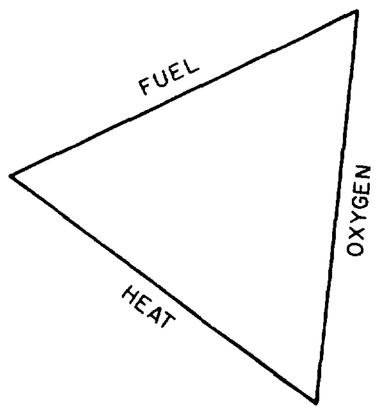

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Figure 4-1.—The fire triangle.

which a flammable substance gives off vapors that will burn when a flame or spark is applied is known as the FLASH POINT. THE FIRE POINT is the temperature at which the fuel will continue to burn after it has been ignited. The fire point is usually a few degrees higher than the flash point. The *auto-ignition* or *self-ignition point* is the lowest temperature to which a substance must be heated to give off vapors that will burn without the application of a spark or flame. In other words, the auto-ignition point is the temperature at which spontaneous combustion occurs. The auto-ignition point is usually at a much higher temperature than the fire point.

The range between the smallest and the largest amounts of vapor in a given quantity of air that will burn or explode when ignited is called the *flammable range* or the *explosive range.* For example, let us say that a substance has a flammable or explosive range of 1 to 12 percent. This means that either a fire or an explosion can occur if the atmosphere contains more than 1 percent but less than 12 percent of the vapor of this substance. In general, the percentages referred to in connection with flammable or explosive ranges are percentages by volume.

FUEL

One of the components of the fire triangle is fuel. Fuels take on a wide variety of characteristics. A fuel may be a solid, liquid, or even a vapor. Some of the fuels you will come into contact with are rags, paper, wood, oil, paint, solvents, and magnesium metals. This is by no means a complete list, but only examples.

OXYGEN

The air that you breath contains 20.8 percent oxygen. All fires need oxygen to continue to burn. Some fires will burn with only 6 percent oxygen. However, there are some fires that will produce their own oxygen. Further discussion on oxygen and its association with the control and extinguishment of fires will be covered in the appropriate sections of this chapter.

FIRE CLASSIFICATIONS

Fires are classified according to the nature of the combustibles (or fuels) involved. The classification of any particular fire is of great importance since it determines the manner in which the fire must be extinguished. Fires are classified as being either class ALFA, class BRAVO, class CHARLIE, or class DELTA fires.

Class ALFA (A) fires are those that occur in such ordinary combustible materials as wood, cloth, paper, upholstery, and similar materials. Class A fires are usually extinguished with water, using high or low velocity fog or solid streams. Class A fires leave embers or ashes and must always be overhauled.

Class BRAVO (B) fires are those that occur in the vapor-air mixture over the surface of flammable liquids, such as gasoline, jet-fuels, diesel oil, fuel oil, paints, thinners, solvents, lubricating oils, and greases. Dry chemical (PKP), aqueous film forming foam (AFFF), HaIon 1301, carbon dioxide (CO_2), or water fog can be used to extinguish class B fires. The agent you use will depend upon the circumstances of the fire.

Class CHARLIE (C) fires are those which occur in electrical equipment. Nonconducting extinguishing agents, such as PKP, CO_2, and Halon 1301 are used to extinguish class C fires. Carbon dioxide and Halon 1301 are preferred because they leave no residue.

Class DELTA (D) fires occur in combustible metals, such as magnesium, titanium, and sodium. Special techniques have been developed to control this type of fire. If possible, the burning material should be jettisoned overboard. Most class D fires are fought by applying large amounts of water on the burning material to cool it down below its ignition temperature. However, magnesium fires can be smothered by covering the magnesium with lots of dry sand.

THE EFFECTS OF FIRE

A burning substance produces a number of chemical reactions. These reactions produce flames, heat, smoke, and number of gases and other combustion products. The gases and combustion products will reduce the amount of oxygen available for breathing. All of these effects are vitally important to you as a fire fighter. You must be prepared to protect yourself against them.

FLAME, HEAT, AND SMOKE

Personnel must be protected from the flames, heat, and smoke to avoid injuries or loss of life. Before you enter a compartment or area where there is a fire, you need to be dressed-out properly.

You will need to tuck your pants into your socks, button the collar on your shirt, and put on a helmet. Wear any other protective clothing prescribed by current directives. If you are a nozzleman or hoseman, you will also need to wear protective gloves and an oxygen breathing apparatus (OBA). The flames and heat from a fire can be intense. However, if you are dressed out properly and maintain adequate distance, you can minimize your chances of getting burned. The smoke will make it hard to see and breath. However, you can cope with these problems by wearing an OBA and a headlamp.

GASES

Some of the gases produced by a fire are toxic (poisonous). Other gases although nontoxic are dangerous in other ways. We will discuss briefly some of the more common gases that are associated with fires.

Carbon Monoxide

Carbon monoxide (CO) is produced by a fire when there is not enough oxygen present for the complete combustion of all of the carbon in the burning material. CO is a colorless, odorless, tasteless, and nonirritating gas. However, it can cause death even in small concentrations. A person who is exposed to a concentration of 1.28 percent CO in air will become unconscious after two or three breaths. They will probably die in 1 to 3 minutes if left in the area. CO also has a wide explosive range. If CO is mixed with air in the amount of 12.5 to 74 percent by volume, an open flame or even a spark will set off a violent explosion.

Carbon Dioxide

Carbon dioxide (CO_2) is produced by a fire when there is complete combustion of all of the carbon in the burning material. CO_2 is a colorless and odorless gas. Although CO_2 is not poisonous, unconsciousness can result from prolonged exposure at 10 percent volume and higher. Above 11 percent volume, unconsciousness can occur in one minute or less. In a sufficient quantity, death could occur, since CO_2 does not provide any oxygen to breathe. The danger of asphyxiation should not be taken lightly; CO_2 does not give any warning of its presence, even when it is present in dangerous amounts. It does not support combustion and it does not form explosive mixtures with any substances. Because of these characteristics, CO_2 is very useful as a fire extinguishing agent. It is also used for inerting fuel oil tanks, gasoline tanks, and similar spaces.

Hydrogen Sulfide

Hydrogen sulfide (H_2S) is generated in some fires. It is also produced by the rotting of foods, cloth, leather, sewage, and other organic materials. H_2S can be produced within 6 to 12 hours. Use caution when fighting fires around sewage systems and in spaces where there has been a sewage spill. H_2S is a colorless gas that smells like rotten eggs. Air that contains 4.3 to 46 percent H_2S is violently explosive in the presence of a flame. H_2S is extremely poisonous if breathed, even in concentrations as low as 20 ppm. You may rapidly become unconscious, stop breathing, and possibly die after one breath in an atmosphere that contains 1,000 to 2,000 ppm of H_2S.

Hydrogen Chloride

Hydrogen chloride (HCl) is emitted by fire-retardant paper (Federal Specification UU-P-268) when the paper is exposed to temperatures of 200°F (93°C). Also, Flexifloor tile MT 202 (Butyl rubber MI L-M- 15562) exposed to temperatures of 400°F (204°C) will emit HCl. The level of HCl emitted is four times the authorized safe level of 5 ppm. Breathing concentrations of 1500 ppm is fatal in just a few minutes.

Hydrogen chloride is a colorless, nonflammable gas, which is soluble in water. The gas could be found in a mist form. It is corrosive to the eyes, skin, and mucous membranes. If you have a fire in a compartment where fire-retardant paper or tile is located, be sure to wear an OBA until the compartment is tested and found safe for personnel without an OBA.

Phosphine

Phosphine (PH_3) is also emitted by fire-retardant paper (Federal Specification UU-P-268) when the paper is exposed to temperatures of 200°F (93°C). Flexifloor tile MT 202, (Butyl rubber MIL-M-15562,) will also emit PH_3 when exposed to temperatures of 400 “F (204 ‘C). The level of PH_3 emitted is 23 times the authorized safe level of 0.3 ppm.

Phosphine is a colorless gas that has an odor of decaying fish. It is soluble in water and in organic solvents, and it ignites at a low temperature. The odor of the gas may be nauseating. When PH_3 is suspected, wear an OBA until atmospheric tests show that the area is safe.

INSUFFICIENT OXYGEN

A fire in a closed compartment may cause an inadequate supply of oxygen for breathing. An enormous amount of oxygen is used by the fire itself, leaving relatively little oxygen to breathe. The amount of oxygen normally present in the air is 20.8 percent. You breathe and work best with this amount of oxygen. When a space is suspected of having an insufficient amount of oxygen, wear an OBA. Keep the OBA on until atmospheric tests show that oxygen content is at least 20 percent and no more than 22 percent by volume.

FIRE EXTINGUISHMENT

In general, fires may be extinguished by removing one side of the fire triangle (fuel, heat, or oxygen) or by slowing down the rate of combustion. The method or methods used in any specific instance will depend upon the classification of the fire and the circumstances surrounding the fire.

THE REMOVAL OF FUEL

Although it is not usually possible to actually remove the fuel to extinguish a fire, there may be circumstances in which it is possible. If part of the fuel that is near or actually on fire can safely be jettisoned over the side, do so as soon as possible. Damage control parties must stand ready at all times to shift combustibles to safe areas. Take whatever measures possible to keep additional fuel away from the fire. In particular, immediately close supply valves in fuel oil, lube oil, and JP-5 lines.

THE REMOVAL OF HEAT

The fire will go out if you can remove enough heat by cooling the fuel to a temperature below that at which it will support combustion.

Heat may be transferred in three ways: by radiation, by conduction, and by convection. In the process known as radiation, heat is radiated in all directions. Radiated heat is what causes you to feel hot when you stand near an open fire. In conduction, heat is transferred through a substance or from one substance to another by direct contact from molecule to molecule. Therefore, a thick steel bulkhead with a fire on one side can conduct heat from the fire and transfer the heat to the adjoining compartments. In convection, the air and gases rising from a fire are heated. These gases can then transfer the heat to other combustible materials that are within reach. Heat transferred by convection is a particular danger in ventilation systems. These systems may carry the heated gases from the fire to another location several compartments away. If there are combustibles with a low flash point within a compartment served by the same ventilation system, a new fire may start.

To eliminate the heat side of the fire triangle, cool the fire by applying something that will absorb the heat. Although several agents serve this purpose, water is the most commonly used cooling agent. Water may be applied in the form of a solid stream, as a fog, or used together with AFFF.

THE CONTROL OF OXYGEN

Oxygen is the third component of the fire triangle. Oxygen is difficult to control because you obviously cannot remove the oxygen from the atmosphere that normally surrounds a fire. However, oxygen can be diluted or displaced by other substances that are noncombustible.

If a fire occurs in a closed space, it can be extinguished by diluting the air with carbon dioxide (CO_2) gas. This dilution must proceed to a certain point before the flames are extinguished. To reach this point, all ventilation systems to the space must be secured. Once this point has been reached, no fire can exist. In general, a large enough volume of CO_2 must be used to reduce the oxygen content to 15 percent or less.

AFFF foam will also keep oxygen from reaching the burning materials thus smothering the fire.

THE REDUCTION OF THE RATE OF COMBUSTION

Dry chemical fire extinguishing agents and Halon 1301 do not extinguish fires by cooling or smothering. Instead, they are believed to interrupt the chemical reaction of the fuel and oxygen. This reduces the rate of combustion, and the fire is extinguished quickly.

THE IMPORTANCE OF SPEED IN FIRE FIGHTING

Speed is very important in fire fighting. If you allow a fire to burn without confining or extinguishing it, the fire can spread rapidly. A small fire in a trash can may spread to other combustibles and become a large fire that could affect several compartments or even the whole ship. The cost of damage that may have originally been a few dollars could end up costing millions of dollars. Therefore, the ship's fire party must get to the scene with their equipment and start fighting the fire as soon as possible. Any delay that allows the fire to spread will make it more difficult to extinguish the fire with the personnel and equipment available.

EXTINGUISHING AGENTS

The agents commonly used by Navy fire fighters include water, AFFF, dry chemicals, carbon dioxide (CO_2), and Halon 1301. The agent or agents that you will use in any particular case will depend upon the classification of the fire and the general circumstances.

WATER

Cooling is the most common method of fire extinguishment, and water is the most effective cooling agent. Fortunately, water is available in large quantities. Of all the extinguishing agents being used by the Navy, water has the greatest capacity for heat absorption. Therefore, you can cool most burning substances below their ignition points by the application of water.

Aboard ship you will normally apply water to the fire by the use of an all-purpose nozzle. We will discuss the all-purpose nozzle in more detail in chapter 5 of this training manual. The all-purpose nozzle allows you to apply water to the fire as a solid stream, as high velocity water fog, or as low velocity water fog. When you need to reach a fire that is some distance away, or when you need penetrating power, you should use the solid stream. However, water fog is preferred over a solid stream in most cases. A given amount of water in the fog will absorb more heat than the same amount of water in a solid stream. The total amount of water that must be pumped into the ship to fight a given fire will also be reduced when using the fog. All water used for fire fighting must be pumped overboard or otherwise disposed of; this is a definite advantage of using the fog form. In addition to cooling the fire, fog tends to smother the fire by displacing the oxygen.

Because of the cooling capacity of the finely divided water particles, fog can be used successfully on class B fires as well as on class A fires. If you use fog on a class B fire, you need to remember that a danger of a reflash exists until you cool the entire surface of the fuel down below the flash point.

Water is not recommended as an extinguishing agent for electrical fires except as a last resort. When water is properly broken up into a fine spray or fog by the nozzles operating at the designed pressure, the fog does not conduct electric current. But if you shift to a solid stream, or if you accidentally touch the nozzle or the applicator to the electrical equipment, the danger of electrical shock is great. Sometimes it may be necessary to use water fog to fight an electrical fire. In these cases, do not advance the nozzle any nearer to the power source than is absolutely necessary for proper use of the fog pattern.

Water fog gives you considerable protection by forming a screen of water droplets between you and the fire. This fog screen protects you against the intense heat of the fire. This gives you a certain amount of maneuverability in attacking the fire. Water fog also tends to dilute or absorb various vapors and to wash fumes and smoke from the atmosphere. You can help clear smoke from the area by occasionally directing the fog pattern upward for a few seconds.

Before you enter a burning compartment, reduce the heat and flame by a liberal application of water fog. Place the fog into the compartment through doors and other accesses. In the early stages of a large fire, a good deal of the fog applied will turn into steam. The steam will help to smother the fire. You must remember to stand clear of openings, since there is likely to be a violent outward rush of hot gases that are displaced by the steam.

FOAM

Foam is a highly effective extinguishing agent for smothering large fires, particularly those in oil, gasoline, and jet fuels.

AFFF, also known as "light water," is a synthetic, film-forming foam designed for use in shipboard fire fighting systems. The foam proportioning/injection equipment generates a white foam blanket. AFFF proportioning equipment will be discussed in chapter 5 of this training manual. AFFF is equivalent to seawater when it is used to extinguish class A fires.

The unique action of AFFF stems from its ability to make a light-water film float on flammable fuels. As foam is applied over the flammable liquid surface, an aqueous solution drains from the foam bubbles and floats out over the surface to provide a vapor seal. This aqueous film-forming action enhances extinguishment and prevents reflash, even when the foam blanket is disturbed. Fuels which have not been ignited may also be protected with this same action.

AFFF can be used alone or in combination with Purple-K-Powder (PKP), which will be discussed in the next section.

DRY CHEMICALS

Dry chemical powders extinguish a fire by a rather complicated chemical mechanism. They do not smother the fire and they do not cool it. Instead, they interrupt the chemical reaction, known as fire, by suspending fine particles in the fire. In effect, the dry chemicals put a temporary screen between the heat, oxygen, and fuel and maintain this screen just long enough for the fire to be extinguished.

Several types of dry chemicals have been used as fire extinguishing agents. For Navy use, the most important agent of this kind at present is potassium bicarbonate, also known as Purple-K-Powder or PKP. PKP is used to extinguish class B and class C fires because it is very effective against these fires. However, it is both corrosive and abrasive and should be used on class C fires only in emergencies. PKP is primarily used in portable 18-pound extinguishers. However, 9- and 27-pound portable extinguishers are also available for portable use. PKP can be used in conjunction with AFFF. Portable PKP extinguishers and the special equipment for using PKP and AFFF together are described in chapter 5 of this training manual.

CARBON DIOXIDE

Carbon dioxide (CO_2) is an effective agent for extinguishing fires by smothering them. That is, CO_2 reduces the amount of oxygen available for combustion. This smothering action is temporary. You must remember that the fire can quickly rekindle if oxygen is again admitted to hot embers.

CO_2 is a dry, noncorrosive gas that is inert when in contact with most substances. It is heavier than air and remains close to the surface. CO_2 does not damage machinery or other equipment. Since it is a nonconductor of electricity, CO_2 can safely be used to fight fires that might present electric shock hazards. However, the frost that collects on the horn of a CO_2 extinguisher does conduct electricity. Therefore, you should be careful and never allow the horn to come into contact with electrical components.

Aboard ship, CO_2 fire extinguishing equipment includes 15-pound CO_2 extinguishers, 50-pound CO_2 hose and reel installations, and 50-pound CO_2 installed flooding systems.

Although CO_2 is nonpoisonous, it is dangerous because it does not provide a suitable atmosphere for breathing. Asphyxiation can result from breathing CO_2. OBA's must be worn when CO_2 is used below decks or in confined spaces.

HALON 1301

Halon 1301 (bromtrifluoromethane) is a relatively new fire extinguishing agent used in the Navy. Halon 1301 is a colorless, odorless gas with a density approximately five times that of air. It does not conduct electricity or leave a residue. Halon 1301 is stored in compressed gas cylinders for shipboard use.

This extinguishing agent is effective against class A, class B, and class C fires. The fires are not extinguished by smothering or cooling. The chemical reaction of fire is interrupted, as is the case of using PKP. HaIon 1301 decomposes upon contact with flames that are approximately 900°F (482°C). For Halon 1301 to function effectively as an extinguishing agent, it must decompose. However, as it decomposes, several other products such as hydrogen fluoride (HF) and hydrogen bromide (HBr) are formed. Both gases are irritating to the eyes, skin, and upper respiratory tract. Chemical burns are also possible.

You should not stay in a space where HaIon 1301 has been released unless you are wearing an OBA. However, you can safely be exposed to concentrations of 5 to 7 percent for a period up to 10 minutes. In fact, carbon monoxide along with oxygen depletion, heat, and smoke present a greater danger to you than Halon 1301. Chapter 5 of this training manual will discuss Halon 1301 fire extinguishing systems.

SUMMARY

In this chapter, you were introduced to the fundamentals of fire fighting. We identified the three elements required to have a fire along with the classifications of fires. You should now be aware of the effects of fire and the different types of gases you may encounter while fighting a fire. Remember, no two fires are identical; you will have to determine the best method or extinguishing agent to use when fighting a fire. Safety is to be observed always. *Never* assume a compartment's atmosphere is safe for humans. A deadly gas may be present just waiting for a victim. Do not let the victim be you. The equipment used to test a compartment's atmosphere will be discussed in chapter 6 of this training manual.